Boston University, are working together to develop systematic criteria for the evaluating investments in strengthening health research capacity. Their activities have been driven by programme officers' desire to know if the research capacity strengthening investments make sense and spurred by the demands of donor agencies to document the results and impacts of the investments.

Three levels of impact are being measured: on individual researchers, national research insitutions, and the global health research system. Special attention is being paid to develop measurable indicators of the impact of these research investments on improvements in policies and programmes. Linking changes in population health status to specific investments in health research and capacity strengthening is extremely difficult. More progress has been made in developing a consensus on indicators of individual research skill development, research productivity, and individual career development. Measuring improvements in equity still has a long way to go. The Rockefeller Foundation has identified this as one of the subthemes of its health equity programme (www.rockfound.org/programs/healthequity/).

Those of us committed to strengthening health research capacity believe that an honest, systematic evaluation of the impacts of these efforts is becoming increasingly important as global scientific and political imperatives lead us into an era in which more funds will be invested in developing country scientists and institutions. Boosting the quantity and quality of scientific research carried out in developing countries is essential. But it is equally essential that the inevitably limited resources are well spent. This type of honest appraisal is a key element of *kalayanamitra,* or friends-helping-friends.

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Health technology transfer

Eva Harris, Marcel Tanner

Global health relies on biomedical scientists and public health workers to solve infectious disease and other health problems at a local level. Yet investigators in developing countries face tremendous obstacles; scientific isolation, insufficient technical training and research tools, a lack of up to date scientific information, and limited financial, material, and human resources. To build local scientific capacity to monitor and control disease and to promote health, research on locally relevant issues must be supported and sustainable partnerships built to facilitate these efforts. We discuss key elements for transfer of technologies in health research and present two case studies of such programmes.

Summary points

More funding must be made available to scientists in developing countries and to organisations that support in-country training and research

Genuine partnership and mutual trust is a prerequisite for the sustainable transfer of technology from developed to developing countries

Building local scientific capacity and long term North-South and South-South partnerships are important in establishing effective health research programmes

Research topics should have local relevance and priority, and technology transfer should be participatory, equitable, and sustained

Autonomous research centres attract funding and reduce administrative burdens

Division of Infectious Diseases, School of Public Health, University of California, Berkeley, CA 94720, USA
Eva Harris
assistant professor

Swiss Tropical Institute, Basle, Switzerland
Marcel Tanner
director

Correspondence to: E Harris
eharris@socrates.berkeley.edu

BMJ 2000;321:817–20

Developing countries need up to date technologies

Though 93% of the world's burden of preventable mortality occurs in developing countries,[1] too little research funding is targeted to health problems of developing countries, creating a dangerous funding differential.[2] In addition, many modern laboratory technologies remain inaccessible in these nations. Both utilitarian and humanitarian arguments can be made for training scientists and health professionals in developing countries in the use of modern laboratory and epidemiological skills. It takes only a day or two for a pathogen to get from any one place on the planet to any other; thus, building capacity in developing countries is a necessary strategy for preventing the global spread of infectious agents.[3] Additionally, as a matter of principle, all countries, especially those with high burdens of disease, should have access to the most effective tools to control their infectious disease problems.

Key elements in technology transfer

Through transferring biomedical technologies and conducting collaborative research in resource poor countries, we have identified key elements in the technology transfer process. In addition to technical issues, successfully implementing a new technology depends on economic support, political cooperation, functional infrastructure, good communication, and an understanding of sociocultural issues, and environmental concerns. Though likely to be beyond the direct control of the investigator, these factors can be

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Details of the case studies are available on the BMJ's website

The 11 principles of research partnership[4 5]

1. Decide on objectives together
2. Build mutual trust
3. Share information and develop networks
4. Share responsibility
5. Create transparency
6. Monitor and evaluate the collaboration
7. Disseminate results
8. Apply the results
9. Share profits equitably
10. Increase research capacity
11. Build on achievements

addressed by well defined research partnerships (see box).[4 5]

Sophisticated and expensive technologies can be made cheaper and more accessible by designing or modifying equipment to suit local conditions—for example, converting a blender into a centrifuge or a record turntable into a lab shaker (fig 1). Techniques can be simplified too—for example, manual amplification with water baths instead of a thermocycler to conduct the polymerase chain reaction (PCR); streamlining protocols—for example, collecting and drying blood samples on filter paper to eliminate the need for the cold chain; preparing reagents in house; recycling; and using donated materials, and outdated but functional equipment.[6] Breaking the transfer process down into its component parts allows problems to be addressed one by one, so that what initially seemed overwhelming becomes manageable.

To achieve sustainable transfer of knowledge, the transfer process must be based on a genuine partnership that is founded on the concept of reciprocal exchange. An equitable, participatory, and knowledge based approach in which everyone plays a role is essential. Along with the technology itself, a thorough understanding of the principles underlying the technology needs to be transmitted for independence to be achieved. Clearly, for any new concept or technology to be integrated into the existing system, the initiative must come from the recipients.

Many innovations come from scientists in developing countries—for example, shortening a three day enyme linked immunoassay (ELISA) for dengue virus to four hours with comparable sensitivity and specificity (Nicaragua) and developing a micro-ELISA with a total reaction volume of 10 μl to minimise reagent use (Cuba).

Whereas the initial transfer of knowledge is often rapid and can be achieved in an intensive training workshop, the implementation process is gradual and requires sustained, long term follow up. Appropriate follow through requires the technology "donor" to serve as a long term resource for scientific consultation, technical guidance, relevant bibliographical information, and often, materials and reagents. Inadequate follow up is the reason why many efforts to transfer technology fail. A key contact who is willing to work tirelessly to ensure the success of the project is critical, as is commitment, responsibility, and lack of self interest on the part of all involved.

Examples of technology transfer programmes

We present two models for sustainable transfer of technology and establishment of long term collaborations; the first example emphasises technology transfer itself and the second shows the context of successful technology transfer (further details of both are available on the *BMJ*'s website).

Sustainable Sciences Institute in San Francisco

The non-profit making Sustainable Sciences Institute (SSI; www.ssilink.org), was founded in 1998 to effect the appropriate transfer of laboratory and epidemiological techniques to developing countries. Its goal is to help local biomedical scientists gain access to training, funding, information, collaborators, equipment, and supplies so that they can better address infectious disease problems in their communities. The institute has four main programme areas and emphasises long term follow up in the form of technical, financial, and material support.

The on-site training programme provides integrated training in laboratory techniques, epidemiology, and scientific writing. Participants form inter-institutional teams around relevant infectious diseases and are instructed by scientists from other countries in the region as well as from the United States. The institute provides continued material and technical support to ensure the success of projects initiated in the workshops.

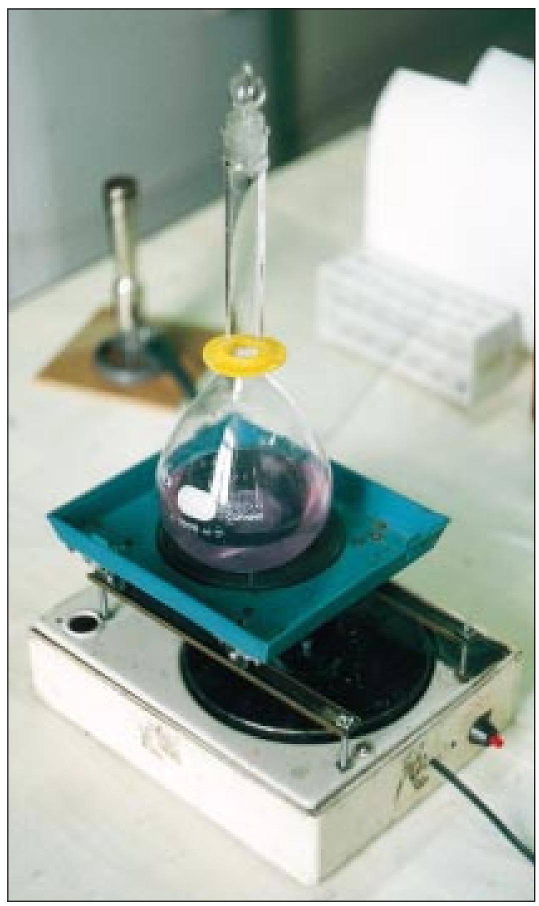

Fig 1 Modifying equipment locally: the turntable of a record player becomes a lab shaker

Fig 2 Laboratory skills are taught to local scientists in Bolivia

The small grants programme provides support to researchers without access to alternative funding. This seed money helps produce locally relevant scientific results that serve as preliminary results for grant applications to larger agencies. Applicants can submit grants in their native language and send in preliminary proposals for constructive feedback.

The networking and consulting programme consists of a database of experts in the health sciences who provide voluntary consultation to researchers in developing countries. This will soon become web based, so that interested scientists can contact each other directly.

The material aid programme facilitates the transfer of scientific equipment and supplies from laboratories in developed countries to researchers in developing countries.

Through SSI and its precursor, the Applied Molecular Biology/Appropriate Technology Transfer Program,[6–8] over 350 scientists and health professionals from 18 developing countries have been trained. Workshops have been held in Nicaragua, Guatemala, Ecuador, Bolivia, Cuba, and the United States and have resulted in many collaborative research projects, locally funded proposals, and scientific publications.[9–13]

Positive impact on public health

The public health impact of SSI's approach is illustrated by the long term partnership developed over 12 years between investigators at the University of California and the Ministry of Health in Nicaragua. Through collaboration with the department of parasitology, PCR techniques for the diagnosis of the parasitic disease leishmaniasis were simplified and have been used routinely in Nicaragua for the last decade.[11] New molecular typing methods were developed[14] and led to the discovery of a new form of the disease (atypical cutaneous leishmaniasis). Further research studies were conducted,[12] and the Ministry of Health incorporated information about recognition, diagnosis, and treatment of atypical cutaneous leishmaniasis into a public education campaign.

Members of the department of virology have been trained in numerous techniques for diagnosis and characterisation of dengue virus; routine use of these methods has improved epidemiological surveillance at a national level.[10] In 1995, these researchers used newly incorporated techniques to rule out dengue virus as the cause of an outbreak of haemorrhagic fever in northern Nicaragua. Subsequently, international teams of scientists identified the leptospira bacterium as the culprit, and antibiotics were distributed; since then, leptospirosis has become recognised as a major emerging pathogen. Management of this epidemic depended on the ability of Nicaraguan researchers to initiate a rapid and reliable scientific investigation.

The Ifakara Health Research and Development Centre in Tanzania

The Ifakara Health Research and Development Center (IHRDC; ifakara.ihrdc@twiga.com)[15] started life in 1957 as a field station set up by the Swiss Tropical Institute, its remit being to investigate the biology and epidemiology of parasitic diseases. Priorities were initially set by Northern scientists, but after Tanzanian independence the role of the centre was reassessed and as a result of joint evaluation assumed a national identity as a research and resource centre to help implement Tanzanian health development programmes. Since 1997, the IHRDC has operated as a Tanzanian trust that attracts substantial projects, ranging from epidemiological studies to clinical trials and health systems research. The centre was the site of the first African malaria vaccine trial.[15 16]

Local priorities guide the research undertaken at the centre as well as the technology applied. For example, research on the resistance of plasmodia to the commonly used anti-malarial drugs has been a priority for the past 20 years and was accompanied by technology transfer at all stages. Initial studies used standard

Other examples of advancing research in developing countries

International research centres—Another approach to advancing research on priority health problems in developing countries has been the creation of international centres of research—for example, International Center for Diarrheal Disease Research, Bangladesh (www.icddrb.org.sg); Institute for Nutrition for Central America and Panama, Guatemala (www.incap.org.gt); the CGAIR network (www.cgiar.org).

The advantages of such institutes are that they provide conditions for a critical mass of scientists to come together to attack a specific problem and produce important short term results. The disadvantages include the high operational cost, friction caused by the salary differential between foreign and local staff, exclusion of national health priorities by external research agendas, and variability in the extent of technology transfer to local staff.[1]

Combinations of approaches—The International Center for Genetic Engineering and Biotechnology (ICGEB), with headquarters in Trieste and New Delhi (www.icgeb.trieste.it), combines a number of approaches, including short term training through courses and meetings and long term training through both fellowships to work at ICGEB laboratories and support for collaborative research projects in member countries.

Short courses—Another model for technology transfer consists of short courses in different subject areas that are sponsored by a variety of international organisations, universities, and non-governmental organisations. These afford important training and networking opportunities to participants but often insufficient follow up.

WHO monitoring protocols, but more recent work has applied PCR technology to identify markers for pyrimethamine and sulfadoxine resistance at the molecular level.[17] Another example is the introduction of techniques for genotyping malaria parasites. As soon as new technologies became available, transfer processes were initiated and consisted of initial training periods abroad or on site, followed by visits by Northern scientists. [18]

Research programmes range from biomedical to social sciences and are accompanied by continuous training programmes. During the past 15 years, 27 MSc degrees and eight PhDs have been awarded to Tanzanian scientists, and at least 10-15 papers have been published in peer reviewed journals each year.[19–26] At present the centre is competent and internationally competitive to undertake basic epidemiological, parasitological, immunological, and clinical studies; conduct and analyse clinical trials; perform PCR based genotyping of plasmodia; and undertake health systems research.

Lessons learnt from the programmes

- Long term partnership between collaborators in the North and South is needed
- Financial, material, and technical support must be sustained[2 27]
- The regional and sociocultural context of each technology transfer must be considered
- Local priorities should inform all basic or applied research undertaken
- Research and training must be linked to public health action
- Building South-South links is important.

Conclusions

Scientific capacity building in developing countries is urgently needed to improve health worldwide and curb the global spread of infectious diseases. By giving scientists in developing countries the skills and materials needed to combat locally prevalent disease problems—for example, malaria, tuberculosis, dengue, AIDS, schistosomiasis, and diarrhoeal and respiratory illnesses—these nations can be empowered to take charge of their own development and health status and lessen the global burden of disease.

To improve health research and outcomes worldwide, more funding must be made available to developing country researchers and to organisations that support them. Another critical area of emphasis is translating research into action, along with facilitating communication between researchers and government officials, the media, and the general public. Numerous promising examples, including those mentioned here, show that by strengthening local scientific capacity and forming lasting partnerships, research on health issues that affect the vast majority of the world's population can be addressed more effectively.

The equipment in fig 1 was designed and constructed by Nataniel Mamani, Universidad Mayor de San Andrés, La Paz, Bolivia.

We thank Tina Knight, Christine Rousseau, Leila Smith, Josefina Coloma, and Naomi Sager for helpful editorial comments, and we are grateful to all of our colleagues worldwide who have worked tirelessly to make these programmes a success and to the donors who have assured the successful implementation of the programmes by providing long term support.

Competing interests: None declared.

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